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TECHNICAL ISSUES RELATED TO EMISSION RELEASES FROM SUBSLAB RADON MITIGATION SYSTEMS[++]

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ABSTRACT- Surveys of government and private sector radon mitigation activities indicate that subslab radon mitigation systems account for more than 50 percent of all installed systems. While ongoing mitigation research and demonstration projects show promise for optimizing system designs in the future, current practice relies on the installation of robust (effective oversized) systems. Such systems can remove large quantities of radon laden soil gas from underneath and from around mitigated houses.

This paper presents a preliminary review of the literature and an estimation of the range of emission dilutions that are possible for roof-top and elevated side-of-house emission releases. Operating characteristics of typical subslab systems are used with estimated dilutions to assess posssible emissions reentrainment and downwind effects on houses.

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INTRODUCTION

Since 1986, with the formal announcement of the U.S. Environmental Protection Agency's (EPA) Radon Action Program (EPA, 1986), there has been a growing awareness by the public of the problem of indoor radon. This has resulted in the extensive, voluntary testing of tens of thousands of houses and the identification of thousands of houses with elevated (higher than ambient) radon concentrations. By the summer of 1987 private sector radon mitigators were active in 25 states (EPA, 1987). A survey reporting on about 2000 mitigation installations indicated that more than 50 percent of all installations were active soil gas ventilation (subslab) systems (Leovic, K.W., D.C. Sanchez, and A.B. Craig, 1988). EPA mitigation experience through the end of 1988 continued to corroborate the preference for subslab systems because of their effectiveness, ease of installation, moderate costs, and robustness (Fowler et al., 1989; Turk et al., 1988).

SUBSLAB MITIGATION SYSTEMS

Subslab radon mitigation systems are generally operated as subslab soil gas collection systems. As such they collect radon at its source; viz, as it emanates from the soil. Further, subslab systems may change subslab radon concentrations by increasing the infiltration of ambient air or more distant soil gas to the subslab air space. The effectiveness of subslab systems in reducing indoor radon concentrations is directly related to its ability to maintain a negative pressure in the subslab area relative to the indoor air, thus preventing convective entry of radon into house living spaces. Subslab and subbarrier systems have been used effectively in basement, slab on grade, and crawlspace houses.

While there is extensive evidence of the effectiveness of subslab depressurization systems (SSD) (Turk et al., 1988; EPA, 1988) for reducing indoor radon concentrations, there is a paucity of published information concerning their operating conditions and environmental effects. Table 1 presents typical operating characteristics for SSD mitigation systems.

TABLE 1. Operating Characteristics for Subslab Depressurization (SSD) Systems*

Characteristic	Mitigation Study Locations NJ (Piedmont)	Central Florida
Indoor Rn Concentration [Bq m^{-3}]	8.1×10^2 to 6.3×10^3	3.2×10^2 to 3.8×10^3
Entry Point Rn Concentrat'n [Bq m^{-3}]	4.0×10^2 to 7.5×10^4	7.0×10^2 to 4.2×10^3
Subslab Rn Concentrat'n [Bq m^{-3}]	2.0×10^4 to 3.3×10^6	1.4×10^5 to 8.5×10^5
SSD Exhaust Rn Concentrat'n [Bq m^{-3}]	1.6×10^3 to 3.5×10^4	not available
SSD Exhaust Velocity [m s^{-1}]	2.6 to 8.5**	0.63 to 0.90**
SSD Exhaust Volume [m^3 s^{-1}]	0.021 to 0.070	0.005 to 0.007

*References: Sanchez, et al., 1987; Sextro, et al.,1987; C. S. Fowler, personal communication, February 1989; D. Harrje, personal communication, January 1989.
**In 10.2 cm pipe

The Table 1 data, in conjunction with the following discussion, will provide the basis for an identification of technical issues of interest to the long-term development and improvement of subslab systems.

FUNDAMENTALS OF EMISSION DILUTION NEAR BUILDINGS

Radon releases from SSD mitigation systems will be mixed with the ambient air around a building. Because of the high radon concentrations in SSD system exhausts, it is important to understand the factors that can affect the dilution of the emissons and thus minimize intake of

contaminated air into the emitting building (re-entrainment) or downwind buildings. The potential dilution of the vented radon emission releases was evaluated using information gathered from a review of published literature. Major reviews of literature discussing air flow and procedures for estimating pollutant concentrations near buildings can be found in Meroney (1982) and Hosker (1984).

Most of the present understanding of building dilution has been gained through fluid modeling studies (i.e., scaled models in a wind or a water tunnel). Wind tunnel modeling provides a practical method for evaluating the aerodynamic building influences on pollution dilution without the variability in atmospheric conditions. Also, more detailed measurements are possible in the controlled environment of the wind tunnel. Wind tunnel model simulations require careful consideration of atmospheric similarity criteria (Snyder, 1981). The time-averaged pollution concentrations in wind tunnel model studies simulate field concentrations over a time period for which the wind direction is not too variable (i.e., 10-60 minutes). A weighted average of model measurements for several fixed directions can be used to account for changing wind directions over a longer time period.

The present understanding of the important factors affecting pollution dilution near a building is applied here through an example. This example provides a preliminary look into the effects of dilution.

Roof-top Venting - Consider vented emissions on the roof of a building, 10m deep (L) by 20m wide (W) by 10m high (H). The flow zones over the roof of the building would follow the patterns shown in Figure 1 (Wilson, 1979). The

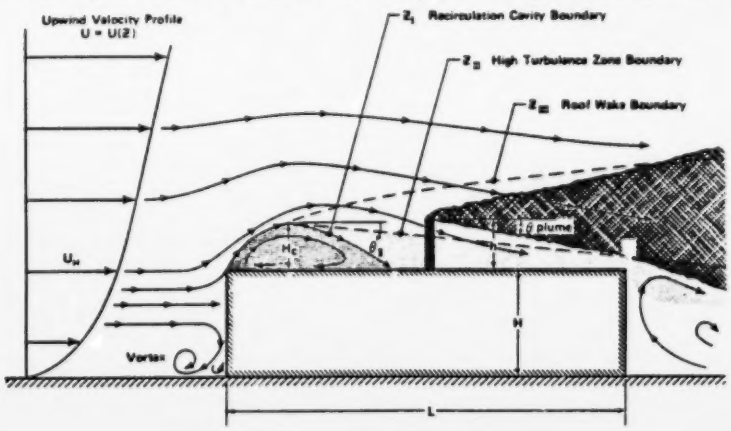

Fig. 1. Flow zones over a building roof for wind normal to the upwind face (depiction based on Wilson, 1979).

"recirculation cavity" zone should extend over the whole roof when the wind direction is such that the downstream dimension of the roof is less than the cross-stream dimension, or building width. For a pitched roof the recirculation zone will lead from its apex instead of the windward edge of the building.

There can be a direct (i.e., short duration without dilution) exchange between the vented SSD emissions and any inlet, such as an open window, that are both within the recirculating zone, for any wind direction. Therefore, the best overall design for minimizing inlet concentrations is to locate the vent near the center of the roof and have any inlet as far away as possible. It is preferable not to locate any inlets on the roof; inlets on the sides of the building will likely be safe from a direct exchange from the vent emissions. A roof stack that is high enough or generates a vertical emissions plume rise greater than 150 percent of the height of the building would be necessary to escape all building downwash effects. A case study is necessary to ensure an understanding of the emission dilution pattern over the building surface, especially if the building does not have a simple block shape or the building surfaces have protuberances. In general, time-averaged roof-vent emission dilution has been found (Wilson, 1976) to be conservatively estimated by equation (1);

$$Ce/Ci = 0.11\ (U/V)\ (S^2/Ae) \qquad (1)$$

where Ce= emission concentration, Bq/m^3
Ci= building surface concentration, Bq/m^3
U = mean wind speed at roof height, m/s
V = vent exit speed, m/s
S = distance along the shortest path from the vent over the building surface to the receptor, m
Ae= vent exit area, m^2

The dilution estimate, Ce/Ci, is a ratio of the ambient mixing volume to the effluent volume. Thus, dilution is increased when the wind speed is higher or the effluent volume is reduced. Emissions from two smaller separated vents will be diluted more than for a combined vent. Present mitigation systems generally have 10.2 cm (4 inch) diameter pipe exits and handle 0.005 - 0.07 m^3/s of effluent. Considering this as an example with U = 5 m/s and S = 2 m, the estimated dilution ranges from 400 to 30; with U = 5 m/s and S = 10 m, the dilution ranges from 10600 to 800. The lower dilution estimates are associated with the larger effluent rates. Larger effluent rates could result in significant plume rise if the vent is

uncapped. Plume rise would result in some additional dilution, which is only significant near the vent. The main effects from uncapped high exhaust rates are the possible elimination of the potential for direct exchange of exhaust between the vent and the inlet, in the recirculation zone, and the elimination of the differences due to varying wind direction (Chui and Wilson, 1988; Li and Meroney, 1983a).

Building-side Venting - Equation (1) has also been found to apply to vent exhaust from the side building surfaces (Wilson, 1977). The air flow around the sides of the building is more complex than over the roof due to its interaction with the ground. Figure 2 depicts the

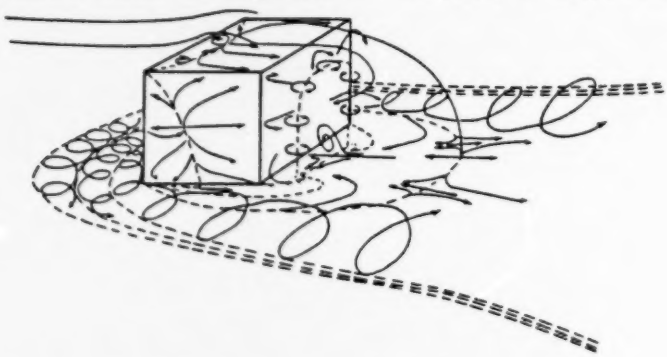

Fig. 2. Flow pattern around a rectangular block (depiction based on Hunt et al., 1978).

complex nature of the flow generated around the building. There is a standing vortex in front of the building which wraps around the sides of the building. Vortices are shed from the back face of the building. Wilson (1977) describes the flow on the building sides. There is downflow on the lower two-thirds and upflow on the upper one-third of the front face. There is a weak upflow on the rear face. There is upwind or downwind flow on the sides depending on the extent of the recirculation region. Dilution of the vented exhaust tends to be lower near the ground due to a lower wind speed and ground reflection.

Dilution in the highly turbulent region downstream of the building is influenced by its mixing volume. In general, emission dilution in this region has been found to be estimated by equation (2);

$$Ce/C = B(U/V)(A/Ae) \qquad (2)$$

where C = ground-level concentration, Bq/m^3
B = constant
A = cross-stream building area, m^2

Values for B should range between 0.2 and 1 based on the review and analyses of Wilson and Britter (1982). Huber (1989) found B to be 0.33-0.66 for a block-shaped building similar to the example being evaluated here. The lower values for B resulted when the wind incidence angle to the wide side of the building was greater than 45 degrees. Applying these values to the example evaluation here results in dilution estimates ranging from 63900 to 4700. Huber (1989) found that, for a very wide building (W/H > 10), the value for B remains fixed to the value for a W/H = 10 building. For a very wide building the flow over and downstream of the building centerline is not significantly influenced by flow around the sides of the building; i.e., the side flow does not influence the entire cross-stream dilution.

Pollution effluent near buildings is transported downstream as vortices that are shed from the building edges. Video images of smoke emitted near a building have been analysed (Huber, 1988; Huber and Arya, 1989) to provide some characterization of the primary spatial and temporal scales. Figure 3 presents an example time series of the

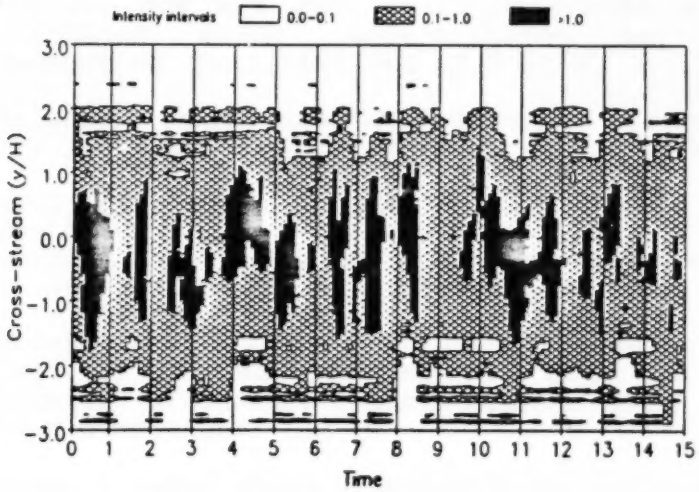

Fig. 3. Contour plot of top-view video image of smoke in the building wake (depiction based on Huber and Arya, 1989).

shed smoke cross-stream profile at a downwind distance of 3 H. The measured smoke intensity, at crosswind distances, y, has been normalized by the mean centerline value. Thus the greater persistence of intensities > 1.0 at y/H = 0. Concentration fluctuations of pollution near buildings has been shown by Li and Meroney (1983b) to have peak-to-mean ratios less than 3. This applies to well mixed regions around the building and within shed

within shed vortices; this does not apply to the fringe regions of the effluent plume where the mean concentrations are very low and high concentrations are very infrequent.

RESULTS AND CONCLUSIONS

1. Subslab depressurization (SSD) system exhaust radon concentrations are about 10 times more than indoor concentrations, about equal to selected entry concentrations, and 10 times less than subslab concentrations. This relationship indicates that subslab systems must collect a significant amount of ambient infiltration air with their soil gas collection.

2. More efficient collection of subslab soil gas should result in being able to downsize current robust SSD mitigation systems and decrease emission exhaust velocities.

3. Dilution of SSD system exhausts by factors of between 200 and 4000 would be needed to reduce exhausted radon concentrations to approach background concentrations of 8 Bq/m^3.

4. Dilution, due to roof-top venting, is more effective for lower effluent rates (exhaust velocities).

5. Roof-top venting or side venting, given dilution distances of 2 and 10 m under moderate winds, can produce dilutions along the building surface of 30 to 400 and 800 to 10600, respectively.

6. Dilutions of 4700 to 64000 are produced in the near wake of the building at the point of maximum downwind ground level concentration under moderate wind conditions.

7. Given a normal range of expected dilutions for roof-top and side-of-building venting, it is probable that reentrainment of SSD exhaust from high concentration and large volume sources may create an elevated indoor radon concentration. Downwind concentration impacts should not be significant.

8. It is plausible that, in localized areas with significant numbers of robust SSD systems in use, measurable increases in ambient short averaging time radon concentrations may be produced.

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